

Calibration Report: Eppley PIR Pyrgeometer

Summary

Calibration Date: April 2012

Calibration Due Date: April 2014

NREL/SRRL Equation and Coefficients:

Serial No.	k_0	k_1	k_2	k_3	K_r	Sigma	$\pm U_{95}(\text{W/m}^2)$
26168F3	-3.679	0.2297	1.0226	-3.01	0.0007044	5.6704E ⁻⁸	2.3
26169F3	-3.033	0.2287	1.0127	-3.12	0.0007044	5.6704E ⁻⁸	2.2

NREL/SRRL Equation:

$$W_{in} = K_0 + K_1 * V_{TP} + K_2 * W_r + K_3 * W_{d-r}$$

Where:

- K_0 , K_1 , K_2 and K_3 = calibration coefficients.
- V_{TP} = thermopile output voltage, in micro-Volt.
- $W_r = \sigma * T_r^4$ = receiver irradiance, in W/m^2 ,
where:
 - $\sigma = 5.6704 * 10^{-8}$, in $\text{W} \cdot \text{m}^{-2} \cdot \text{K}^{-4}$
 - $T_r = T_c + k_r * V_{TP}$ = Receiver temperature, in Kelvin, and $k_r = 0.0007044$
 - T_c = Case temperature, in Kelvin
- $W_{d-r} = \sigma * (T_d^4 - T_r^4)$, in W/m^2 , and T_d = Dome temperature, in Kelvin.

UUT Calibration Coefficients:

26168F3: $K_0 = -3.679$; $K_1 = 0.2297$; $K_2 = 1.0226$; $K_3 = -3.01$
27169F3: $K_0 = -3.033$; $K_1 = 0.2287$; $K_2 = 1.0127$; $K_3 = -3.12$

Uncertainty: (see attached figure for calibration data)

26168F3: $U_{95} = \pm 2.3 \text{ W/m}^2$ (w.r.t. WISG*) with Coverage Factor = 1.96.

26169F3: $U_{95} = \pm 2.2 \text{ W/m}^2$ (w.r.t. WISG*) with Coverage Factor = 1.96.

*World Infrared Standard Group

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Abstract

Two Eppley Laboratory, Inc. Precision Infrared Pyrgeometers (PIR) instruments were calibrated. This calibration was performed in order that the instruments comply with specifications set in the Baseline Surface Radiation Network (BSRN) Operator's Manual, V 2.1, 2005. The National Renewable Energy Laboratory's (NREL) Solar Radiation Research Laboratory (SRRL) Metrology Laboratory in Golden, Colorado performed the calibration. The calibration period was 4 April – 23 April 2012. The serial numbers of the units calibrated were 26168F3 and 26169F3.

1. Introduction

Two Eppley Laboratory, Inc. PIR's were calibrated to meet the 2005 Baseline Surface Radiation Network (BSRN) specifications. NREL's SRRL's Metrology Laboratory in Golden, Colorado completed these calibration tasks.

2. Results

Calibration results for each instrument are shown in the above summary page along with the governing equation. The use of the NREL/SRRL equation with the tabular values is described above. The instruments at COVE will now use the NREL/SRRL equation as it will replace the PMOD equation that was used in previous years. The reason for the change is the NREL/SRRL equation results in better precision (i.e. smaller standard deviation). Also, this equation will be adopted by the ARM program and it is used for all of NREL/SRRL's calibrations.

The Calibration Certificates provided by NREL/SRRL describe their method of calibration.

3. Discussion

These sensors have been calibrated to permit the measurement of diffuse radiation. Global measurements involve determination of the factor f . The manufacturer, Eppley Laboratories, Inc., defines an uncertainty of 5%. Field data need to be examined in order to assess the standard uncertainty made by the calibrated instruments.

Since we used a different equation, the single sensitivity factor calibration histories will be replaced with the four calibration coefficients shown on the first page.

26168F3

Apr. 2012	NREL	$K_0 = -3.679, K_1 = 0.2297, K_2 = 1.0226, K_3 = -3.01$
Jul. 2009	PMOD	4.72 $V/W/m^2$
Mar. 2003	PMOD	4.39 $V/W/m^2$
Jan. 2002	PMOD	4.38 $V/W/m^2$
Sep. 2000	PMOD	4.26 $V/W/m^2$

26169F3

Apr. 2012	NREL	$K_0 = -3.033$, $K_1 = 0.2287$, $K_2 = 1.0127$, $K_3 = -3.12$
Mar. 2007	PMOD	4.15 $V/W/m^2$
Dec. 1999	PMOD	4.07 $V/W/m^2$

The variability between calibrations cannot be compared at this time since we are switching to a new equation. 5% or less variability through each of the calibrations is the manufactured stated design specification.

4. Summary

A calibration of two Eppley Laboratory Inc. PIR instruments has been completed using the new NREL/SRRL equation. This equation will replace the PMOD equation that was used in previous years due to the NREL/SRRL equation providing better precision. Data analyses have been performed. The calibration factors are presented in the summary table above and in the Calibration Certificates.

Please see the archived calibration writeups on the PIR's for information on the old PMOD equation used before switching to the new NREL/SRRL equation. It is located under Pyrgometer at <http://cove.larc.nasa.gov/calibration.html>.

These calibration factors can be used with these two instruments after 24 April 2012.

REFERENCES

Albrecht, B., and S.K. Cox, Procedures for Improving Pyrgometer Performance, Journal of Applied Meteorology, 16, 179-188, 1977.

Frohlich, C., and R. Philipona, Characterization of pyrgometers and the accuracy of atmospheric longwave measurements, Ch., Betz, Applied Optics, 34(9), 1598-1605, 1995.

McArthur, J.B., World Climate Research Program, Baseline Surface Radiation Network Operations Manual, Version 2.1., 2005.

National Renewable Energy Laboratory

Solar Radiation Research Laboratory

Metrology Laboratory

Calibration Certificate

Customer: Science Systems & Applications, Inc. (SSAI)
UUT Model: PIR
UUT Serial Number: 26168F3
Traceability: WISG *, using PIRs: 31197F3
Calibration Period: 04 to 23 April, 2012
Environmental Conditions: Outdoors/variable conditions

Equation:

$$W_{in} = K_0 + K_1 * V_{TP} + K_2 * W_r + K_3 * W_{d-r}$$

Where:

- K_0, K_1, K_2 and K_3 = calibration coefficients.
- V_{TP} = thermopile output voltage, in micro-Volt.
- $W_r = \sigma * T_r^4$ = receiver irradiance, in W/m^2 ,
where:
 - $\sigma = 5.6704 * 10^{-8}$, in $W \cdot m^{-2} \cdot K^{-4}$
 - $T_r = T_c + k_r * V_{TP}$ = Receiver temperature, in Kelvin, and $k_r = 0.0007044$
 - T_c = Case temperature, in Kelvin
- $W_{d-r} = \sigma * (T_d^4 - T_r^4)$, in W/m^2 , and T_d = Dome temperature, in Kelvin.

UUT Calibration Coefficients:

$K_0 = -3.679$; $K_1 = 0.2297$; $K_2 = 1.0226$; $K_3 = -3.01$

Uncertainty: (see attached figure for calibration data)

$U_{95} = \pm 2.3 W/m^2$ (w.r.t. WISG *) with Coverage Factor = 1.96

* World Infrared Standard Group

Certified by : Ibrahim Reda
Title: Senior Scientist V

Signed: 

Date: 04/24/2012

National Renewable Energy Laboratory
Solar Radiation Research Laboratory
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Uncertainty: (see attached figure for calibration data)

$U_{95} = \pm 2.2 W/m^2$ (w.r.t. WISG *) with Coverage Factor = 1.96

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Certified by : Ibrahim Reda
Title: Senior Scientist V

Signed: 

Date: 04/24/2012

**Results for Pyregeometer Outdoor Calibration at SRRL
From 04/06/2012 to 04/23/2012**

	Reference	Test				
	31197F3	30557F3	26169F3	26168F3	30696F3	29926F3
K0	0.45	-0.946477	-3.033366	-3.679045	-0.69874	-3.255402
K1	0.242	0.219921	0.22871	0.229722	0.243237	0.279758
K2	1.004	1.005566	1.01265	1.022586	0.996756	1.012604
K3	-2.61	-2.56	-3.12	-3.01	-3.08	-2.79
Kr	0.0007044	0.0007044	0.0007044	0.0007044	0.0007044	0.0007044
N. Rdg.		2062	2062	2062	2062	2062
+/-U95 W/m ²	1.5	1.9	2.2	2.3	2.2	2.2

Data analysis by: Reda
Date: 04/24/2012